Herd- and sow-related risk factors for lameness in organic and conventional sow herds

Knage-Rasmussen, Kristian Møllegaard; Houe, Hans; Rousing, Tine; Sørensen, Jan Tind

Published in:
Animal

DOI:
10.1017/S1751731113001900

Publication date:
2014

Document version
Early version, also known as pre-print

Citation for published version (APA):
Knage-Rasmussen, K. M., Houe, H., Rousing, T., & Sørensen, J. T. (2014). Herd- and sow-related risk factors for lameness in organic and conventional sow herds. *Animal*, *8*(1), 121-127.
https://doi.org/10.1017/S1751731113001900

Animal, page 1 of 7 © The Animal Consortium 2013
doi:10.1017/S1751731113001900

animal

Herd- and sow-related risk factors for lameness in organic and conventional sow herds

K. M. Knage-Rasmussen[1†], H. Houe[2], T. Rousing[1] and J. T. Sørensen[1]

[1]*Department of Animal Science, Aarhus University, Blichers Allé 20, PO Box 50 DK-Tjele, Denmark;* [2]*Department of Large Animal Sciences, University of Copenhagen, Grønnegårdsvej 8, 1870 Frederiksberg C, Denmark*

(Received 26 February 2013; Accepted 20 September 2013)

Lameness in sows is an animal welfare problem which also presents an economic challenge to pig producers. Information about the prevalence of herd lameness in organic sows is relatively scarce. The first objective of this study was to establish the prevalence of lameness and to identify risk factors associated with sow lameness in Danish outdoor organic sow herds by analysing the association between risk factors at both sow and herd level using clinical records of lameness. A total of 1850 sows from nine organic herds were included in the study. Second, the study examined differences in the prevalence of sow lameness between outdoor organic and indoor conventional herds. An additional aim here was to identify risk factors associated with clinical records of sow lameness in Danish sow herds by analysing the association between risk factors with lameness at sow and herd level. One thousand and fifty four gestation sows from 44 indoor conventional and nine organic sow herds were included in this study. The nine organic herds were visited twice: once in summer/autumn 2011, and once in winter/spring 2012. In winter/spring 2011, a total of 44 indoor conventional herds were visited. Risk factors included in the study were clinical parameters and factors related to the production system. Sows were examined visually by one of four trained observers. The organic sows were assigned scores for lameness, body condition, hoof length, bursitis, abscesses and leg wounds, while the conventional sows were assigned scores for lameness, body condition and bursitis. A multivariable analysis was carried out by logistic regression with the herd and observer as random effects. The average herd lameness prevalence in gestation and lactation sows in organic herds was 11% in summer/autumn and 4.6% in winter/spring. 'Wounds, bursitis and abscess' on legs (OR = 4.7, P *< 0.001) and body condition score >3 (OR = 1.79,* P *= 0.008) were associated with increased risk of lameness in Danish organic sow herds. Season (winter/spring* v. *summer/autumn) lowered the risk of lameness (OR = 0.37,* P *< 0.001). Average prevalence of lameness in gestation sow herds in winter/spring in conventional herds was 24.4%, and in organic herds it was 5.4%. An organic sow had a decreased risk of lameness (OR = 0.28,* P *< 0.001) as compared with a conventional sow. Bursitis was associated with increased risk of lameness (OR = 2.08,* P *= 0.002) regardless of the production system (i.e. whether the herd was organic or conventional).*

Keywords: body condition, hoof lesions, lameness, organic, sows

Implication

Lameness is a welfare problem in sows. It may lead to treatment, or early culling, which can be costly and leave the farmer with an economic loss. This study showed that wounds, bursitis and abscesses should be avoided and that the body condition of the sow should not exceed body condition score 3 if lameness is to be avoided in organic sows. It also showed that organic sows have a lower risk of lameness than conventional sows. The questions that arise concern the factors that decrease lameness in organic sow herds and the possibility to improve animal welfare in conventional herds.

† E-mail: Kristian.knage-rasmussen@agrsci.dk

Introduction

Lameness in sows is an animal welfare problem for the sows. It can also bring unwelcome costs into pig production, because it requires increased labour and medical treatment (Pluym *et al.*, 2011). An expert panel in 2003 suggested that leg disorders and other clinical diseases were underestimated in outdoor sow herds (Bonde and Sørensen, 2003). In Denmark in 2008 mean herd lameness prevalence of 29% in 2989 sows from 33 conventional herds was reported (Jensen *et al.*, 2010). Heinonen *et al.* (2006) found that on-farm lameness prevalence varies from 0% to 27.3%. They estimated mean herd prevalence of 8.8% in Finnish conventional herds. Similar results were found by Pluym *et al.* (2011) in conventional herds in Belgium, where mean herd prevalence of

9.7% was estimated with a range between 2.4% and 23.1%. Studies of the prevalence of sow herd lameness are relatively scarce. Studies in which lameness is given as a main culling reason – and which therefore offer an indirect measure of lameness – are more frequent.

A Swedish study (Engblom *et al.*, 2008) showed that 9% of all cullings in conventional systems were due to lameness; and in US herds the proportion of sows culled in response to locomotive problems was 15.2% in 2006 (USDA, 2007). In Danish herds lameness is again one of the main reasons for culling sows. Vestergaard *et al.* (2004) reported that 10% of culled Danish sows were euthanized, and that 56% of these cases involved locomotive disorders. In a Swedish review the proportion of conventional sows culled as a result of locomotive problems ranged from 6% to 15% of the culled sows (Stalder *et al.*, 2004). Cox and Bilkei (2004) reported that 19% of conventional and 26% of outdoor sows were culled in responses to locomotive disorders in Croatian herds. Akos and Bilkei (2004) found higher levels than Cox and Bilkei (2004), and also identified a disparity in the occurrence of locomotive disorders in conventional and outdoor-housed sows, with 25% of cullings in indoor systems and 39% of cullings in outdoor systems being attributable to lameness. Thus a significantly lower percentage of sows were culled in indoor herds as a result of locomotive problems.

Information about not only the herd prevalence of lameness, but also the rate of cullings caused by locomotive disorders (lameness) and the risk factors involved is scarce for outdoor-housed sows. Bonde *et al.* (2004) found that lameness was associated with skin and hoof wounds, bursitis and abscesses in conventional lactating sows and that thin sows had an increased risk of lameness.

The first aim of this study was to establish the prevalence of sow lameness, and identify its risk factors, in Danish organic sow herds by analysing the association between risk factors and sow and herd-level and clinical recordings of lameness. Second, the study examined differences between outdoor organic and indoor conventional herds in prevalence of sow lameness. An additional aim here was to identify risk factors associated with clinical records of sow lameness in Danish sow herds by analysing the association between risk factors with lameness at sow and herd level.

Material and methods

Selection of herds and animals

Data from two visits to nine organic herds were used (Study A) in connection with the first aim. To achieve the second aim, data from the second visit to the nine organic herds together with data from 44 selected conventional herds, each visited once, were used (Study B). The target population in Study A was the entire population of Danish organic sows and target population in Study B was the entire population of sows in Denmark. The organic sow herds were recruited via an organic adviser group that covers Denmark and produces 70% of all organic slaughter pigs. In all, nine herd owners (Herd size 348, range 110 to 1200 sows) in a study population of 16 herds (Herd size 335, range 50 to 1200 sows) voluntarily agreed to participate in the study. Organic gestation sows in this study had access to pasture all year and were group-fed. For insemination, the sows were loose-housed indoors with access to an outdoor run. The farmers followed standards defined by a company called Friland, the animal rights organization Dyrenes Beskyttelse, and the farmers themselves. The following two features are of particular interest in the present study: (1) the earliest the piglets were weaned was 7 weeks of age, and (2) all sows farrowed in huts on individual pasture paddocks of at least 300 m^2 (Beskyttelse, 2010). The organic sows in this study had access to roughage all year and were erysipelas vaccinated. The organic herds were visited twice: the first visit was made 14 June to 20 October 2011, and the second was made 19 January to 16 March 2012. The period between these two visits was 5 to 9 months, with a median of 7 months. During each visit, ~100 sows (range 88 to 125 sows) were selected by systematic random sampling ((*n* total sow gestation or lactating)/*n* sample = every *n* animal was examined) for clinical examination (Dohoo *et al.*, 2009). The selected sample was stratified so as to include 30% to 40% of lactating sows and 60% to 70% sows in gestation in the organic herds.

The conventional herds were selected from a random sample of 797 Danish sow herds (Jensen *et al.*, 2010) obtained from the central Danish farm database, from which 261 herds were randomly selected. The inclusion criteria were: (1) the herd was located in Jutland or Funen (87% of all live pigs were located here in 2011). This criterion was applied for logistic and cost reasons. (2) The farmer was willing to participate in the investigation. With these criteria applied, 51 herds agreed to participate. It proved impossible to register lameness in seven of these herds as a consequence of the housing system being used. (Briefly, six herds had gestation sows in stalls, where there was insufficient room to get the sow out and into the stalls, and a further herd was group-housed with one eating box per sow, which meant that the sow would not leave the feeding stalls). This left 44 herds for the study with an average herd size of 572 ranging between 130 and 2500 sows. This is comparable to an average conventional herd size of 615 sows with a range up to 3000 sows. Danish conventional sows are housed indoors, mainly in various kinds of gestation group-housing system. However, data on the nature and frequency of the systems were not available. In the present study eight herds had gestation sows in stalls and 36 herds comprised loose-housed gestation sows. The gestation sows were fed separately in feeding stalls or electronic sow feeders if they were not housed in stalls. All sows farrowed in farrowing pens with crates. The piglets were weaned 4 weeks *post-partum*. Each herd was visited once in the period autumn 2010 to spring 2011; and in each herd ~30 sows were selected by systematic random sampling in the gestation section and examined (Dohoo *et al.*, 2009).

Registration methods

During the summer/autumn visit to the organic herds farmers were interviewed by a scientist or technician about management strategies used for feeding (home-mixed *v.* brought-in), gestation group size ($\leqslant$15 *v.* >15 sows), and batch system ($\leqslant$3 *v.* >3weeks). In a follow-up during the winter/spring visit farmers was asked if they had changed the management strategies. None of the farmers had changed anything regarding lameness management. Furthermore, the herd size ($\leqslant$250 *v.* >250), soil type (sand *v.* clay) and visit time (summer/autumn *v.* winter/spring) were recorded. During the winter/spring visit sow status (gestation *v.* lactating) was also recorded.

Clinical examination

Conventional and organic sows were inspected visually from the closest possible distance (0 to 3 m) from the front, behind and both sides in the field, the hut, the barn, or indoor pen, by one out of four trained scientists or technicians. Those involved in this inspection visited eight to 26 herds. Clinical scores were assigned according to Table 1. Where lameness was observed during movement sows were required to walk a minimum of 20 steps, over a 5 to 10 m distance, before the lameness was scored. Indoor the animals were always scored on a concrete surface with or without slatted floor, while outdoor animals were scored on a flat surface with a low level of plant growth. In Study A clinical scores were summarized in three 'new' variables: (1) the accessory digits, hooves and disparately hooves scores were summarized to a dichotomous variable labelled 'hoofs'; (2) the bursitis, wound and abscess scores relating to the legs were summarized to the dichotomous variable 'legs'. Both 'hoofs' and 'legs' scores could be recorded as 'no problem', meaning that the summary score did not exceed a total of zero or 'problem'; (3) the body condition score (BCS) 1 to 5 was divided into two subgroups: fat (BCS > 3) and non-fat (BCS $\leqslant$ 3). At sow level, in Study A, the following potential risk factors were selected for the analysis: 'hoof', 'legs' and BCS at sow level. At herd level risk factors included 'visit', 'herd size', 'soil type', 'feed', 'batch system' and 'gestation group size'. In Study B, body condition was likewise divided into two subgroups: fat (BCS > 3) and non-fat (BCS $\leqslant$ 3). In Study B, BCS (fat *v.* non-fat), bursitis and production system (conventional *v.* organic) were analysed as risk factors for lameness.

Statistical analysis

In both Study A and Study B a univariable logistic analysis not accounting for clustering was performed for each variable at herd or sow level using GLM in R 2.12.2(R 2.12.2). Variables with a *P*-value <0.25 were retained in the following multivariable analysis after testing the cross correlation of individual variables. Biologically meaningful interactions were inserted in the start model using the GLMER procedure in R 2.12.2 (R 2.12.2) from the lme4 package. The multivariable analysis was carried out by logistic regression with herd and observer as random effects. For model reduction, backwards elimination with a 5% significance level was used. Variables that were removed were reinserted to test for confounding in both studies. The initial multivariable model for analysis took the form:

$$\mathrm{Logit}(P_{ij}) = \beta_0 + \beta_1 x_{ij} + \beta_2 x_j + h_j + o_{ij} \qquad (1)$$

where P_i is the probability of sow lameness, β_0 is the model intercept, β_1 represents a vector of fixed effects at sow level, β_0 represents a vector of fixed effects at herd level, x_{ij} is a vector of sow-level variables for sow i in herd j, x_j is a vector of herd variables for herd, h_j represents the random effect of herd and o_{ij} represents the random effect of the observer.

To assess the variation explained by herd and observer in the analysis an interclass correlation of the kind described by Dohoo *et al.* (2009) was calculated. It was formulated:

$$\rho = \sigma^2/(\sigma^2 + \pi^2/3) \qquad (2)$$

where ρ represents the interclass correlation and σ^2 is the cluster variation.

Table 1 *Scores for clinical parameters included in the study*

Parameters	Scoring
BCS[a,d]	1: very thin; 2: thin; 3: normal; 4: fat; 5: very fat
Hoofs	
Accessory digits[b]	0: normal; 1: long (touch the ground when standing on solid surface)
Hooves[b]	0: normal; 1: long (the hooves upper side starting to curve)
Disparately hooves[b]	0: normal; 1: disparate (differ more than 1 cm)
Legs	
Bursitis[c,d]	0: no or small bursitis; 1: bursitis on more than one location, >2 cm, or bleeding
Leg wounds[c]	0: no lesion; 1: wound present (>2 cm length with crust)
Abscess[c]	0: no abscess; 1: abscess present (swelling with inflammation)
Lameness[c,d]	0: normal gait; 1: lame (difficulties walking but using all legs, stride may be shortened and/or there may be swagger of the caudal part of the body when walking)

BCS = body condition score.
[a]Scoring definition according Welfare Quality® (2009).
[b]Scoring definition modified after Bonde *et al.* (2004).
[c]Scoring definition modified after Welfare Quality® (2009).
[d]Scores used in conventional herds.

Results

Descriptive results and herd lameness prevalence

When the farmers in Study A were asked at second interview if they had changed management of lameness it was found that none had done so. In Study A 1850 sows were clinically examined. The average number of examined sows per herd was 103 with a range of 82 to 125. The descriptive analysis of the herd-level and sow-level dependent variables (risk factors) is presented in Table 2.

In Study B a total of 1854 gestation sows were clinically examined. The average number of animals examined was 61 in organic herds and 30 in conventional herds, with an overall average of 35 with a range of 28 to 71 sows. The descriptive analysis of herd and sow dependent variables is presented in Table 3.

In Study A the mean herd prevalence of lameness among nine herds of gestation and lactation sows was 11%, ranging from 3.2% to 16.2%, at the summer/autumn visit. It was 4.6%, ranging from 1.2% to 10.8%, at the winter/spring visit (see Figure 1). In Study B the herd prevalence of lameness in gestation sows was 17%, with a range of 0% to 46.7%. The herd gestation sow prevalence of lameness was 24.3% and 5.4% in the conventional and organic herds, respectively.

Univariable and multivariable analysis

The herd-level risk factors 'visit', 'herd size', 'soil type' and 'gestation group size', and the sow-level risk factors 'legs' and BCS were retained from the univariable analysis and incorporated in the in the hierarchical multivariable logistic model in Study A, as shown in Table 4. System as herd-level variable and bursitis as sow-level variable were retained in the model in Study B.

The risk factors 'visit', 'legs' and BCS were significant ($P < 0.05$) in the final model of Study A. In the analyses no

Table 2 *Descriptive statics of herd- and sow-level explanatory variables stratified with output variable lameness in 1850 sows from nine organic herds*

Variables	Levels	No. of herds	No. of sows	Lameness –	+
Herd level					
Visit	Summer/autumn	9	967	861	106
	Winter/spring	9	883	841	42
Herd size	⩽250 sows	5	983	894	89
	>250 sows	4	867	808	59
Soil type	Clay	3	574	528	46
	Sand	6	1276	1174	102
Feed	Bought in	3	639	599	40
	Home-mixed	6	1211	1103	108
Batch system	⩽3 weeks	7	1454	1341	113
	>3 weeks	2	396	361	35
Gestation group size	⩽15 sows	3	582	544	38
	>15 sows	6	1268	1158	110
Sow level					
Hoofs	No problems		1537	1417	120
	Problems		313	285	28
Legs	No problems		1808	1671	137
	Problems		42	31	11
BCS	⩽3		1586	1468	118
	>3		264	234	30

BCS = body condition score.

Table 3 *Descriptive statics of herd- and sow-level explanatory variables stratified with output variable lameness in 1854 gestation sows from nine organic and 44 conventional herds*

Variables	Levels	No. of herds	No. of sows	Lameness –	+
Herd level					
System	Organic	9	550	1049	255
	Conventional	44	1304	522	28
Sow level					
Bursitis	No problems		1430	1263	167
	Problems		424	308	116
BCS	⩽3		1324	1122	202
	>3		530	449	81

BCS = body condition score.

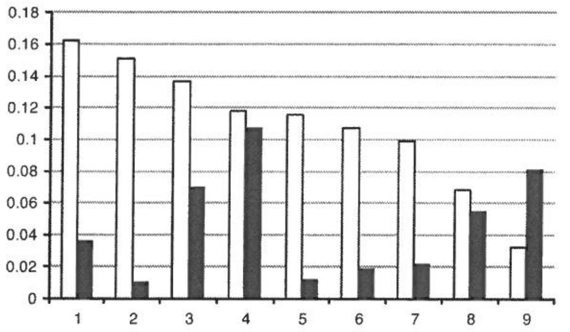

Figure 1 Lameness prevalence (y-axis) at herd level in Danish outdoor herds (one to nine are different herds). The white column is the prevalence recorded during the summer/autumn visit; the black columns indicate prevalence during the winter/spring visit.

Table 4 *Results of univariable analysis of risk factors associated with lameness in organic sows*

Predictor variables	*P*-value
Herd level	
Visit	***a
Herd size	0.06[a]
Soil type	0.13[a]
Feed	0.85
Type of week management	0.75
Gestation group size	0.11[a]
Sow level	
Hoofs	0.55
Legs	***a
BCS	*a

BCS = body condition score.
Predictor variables with *P*-value <0.25 were included in the multivariable model. Logistic analyses with χ^2 test.
[a]Used in multivariable model.
$*P<0.05$; $***P<0.001$.

two-way interaction effect was found. Nor was confounding observed. Calculation of the interclass correlation herd explained 0%, and observer explained 5.7%, of total variation. The odds ratio of lameness among the levels of each significant risk factor is presented in Table 5.

The risk factors 'system' and 'bursitis' were significant ($P<0.05$) in the final model in Study B, as shown in Table 6. In the analyses neither a two-way interaction effect nor confounding were found. Here the calculation of the interclass correlation herd explained 12%, and observer 0.6%, of total variation.

Discussion

Herd lameness prevalence

The mean herd prevalence of lameness in organic sows in summer/autumn was 11%. It was 4.6% in gestation and lactation sows in winter/spring. Heinonen *et al.* (2006) and Pluym *et al.* (2011) reported similar herd prevalence in conventional gestation sows, while Bonde *et al.* (2004) reported higher prevalence in conventional lactating sows. Mean herd prevalence was 5.4% in organic gestation sows; it was 24.3% in conventional gestation sows, which is very similar to the 29% reported by Jensen *et al.* (2010) for group-housed gestation sows in 33 Danish conventional herds, but higher than the 9.7% reported by Pluym *et al.* (2011) in gestation sows in eight Belgian herds.

Herd-related risk factors

The risk of being lame in winter/spring was significantly lower than it was in summer/autumn for organic sows. Figure 1 shows the prevalence and variation of the two seasons. In eight of the nine organic herds the prevalence of herd lameness decreased between summer/autumn and winter/spring. This could indicate that lameness is less of a problem between January and March than it is between June and October.

The management of sows in summer/autumn might have been given a lower priority than that in winter/spring. The main priority in summer/autumn is the harvest, and this might lead to less time being spent on surveillance, which in turn increases the risk of lameness which is not managed correctly.

It might be suggested that the variation in lameness was also a consequence of changes in management resulting from farmers' increased awareness of lameness problems following the first visit. However, the farmers were asked whether they had made any management changes before second visit, and none had done so.

Another possible explanation is the climate, and in particular the condition of the walking surface on the pasture. When the surface is slippery, the risk of lameness is presumably greater, especially if the sows are group fed, as they were in this study, and thus more aggressive. The rainfall in July and August in 2011 was twice the average for these months. This may indeed indicate that the risk of slippery pasture increased, and with it the risk of lameness (DMI, 2013).

Organic gestation sows had a lower risk of lameness than indoor conventional sows. The lower risk in outdoor organic herds is the outcome primarily of the softer surface both in the huts and on pasture. The risk of lameness caused by barn equipment or concrete floors injuries is likely to be less, or zero, in outdoor organic production.

Sow-related risk factors

Leg disorders increased the risk of lameness in organic sows. They have also been found to be a risk factor in conventional sows. Bonde *et al.* (2004) found a significant association of lameness with skin and hoof wounds, bursitis and abscesses in indoor conventional lactating sows. This may be due to the fact that the sows live in very different environment in which the risk factors are different.

Fat sows (BCS > 3) have an increased risk of lameness in organic herds. In a study of conventional lactating sows, Bonde *et al.* (2004) found that fat sows do not have a significantly increased risk of lameness. The association between BCS and lameness may be explained by the fact that the feeding, in outdoor sow herds, is a very competitive affair. It is also relevant that a heavy animal puts more weight on its legs,

Table 5 *Estimates of the significant effects in the model describing lameness among 1850 sows from nine organic herds*

Variable	Estimate	s.e.	*P*-value	OR	95% CI
Intercept	−2.3	0.27	***		
Legs			***		
No problems	1				
Problems	1.55	0.38		4.7	2.18 to 9.70
Visit			***		
Summer/autumn	1			0.37	0.25 to 0.54
Winter/spring	−1.06	0.24			
BCS			**		
<3 BCS	1				
⩾3 BCS	0.61	0.23		1.79	1.13 to 2.77
Random effect	Variance	s.d.		ICC	
Herd	0	0			
Observer	0.20	0.44		5.7%	

BCS = body condition score; ICC = interclass correlation.
$**P<0.01$; $***P<0.001$.

Table 6 *Estimates of the significant effects in the model describing lameness among 1854 gestation sows from 44 conventional and nine organic herds*

Variables	Estimate	s.e.	*P*-value	OR	95% CI
Intercept	−1.73	0.15			
System			***		
Conventional	1				
Organic	−1.43	0.35		0.28	0.18 to 0.42
Busitis			**		
No problems	1				
Problems	0.47	0.15		2.08	1.56 to 2.73
Random effect	variance	s.d.		ICC	
Herd	0.45	0.67		12%	
Observer	0.02	0.14		0.6%	

ICC = interclass correlation.
$**P<0.01$; $***P<0.001$.

which in itself is a risk factor in lameness, and that this will increase when the sows walk on a hard (frozen) or slippery (wet or icy) surface, or have to fight other sows for the feed. BCS is a risk factor for lameness in organic sows, but not conventional gestation sows. This may be because conventional sows are fed individually and a lower BSC variation is expected in them than that found in organic herds, where they are group-fed and high variation is the norm.

In the present study, hoof length and symmetry was not associated with lameness. This confirms the findings of Bonde *et al.* (2004), who examined conventional lactating sows using the same scales as were used here.

We found that sows with bursitis had an increased risk of lameness across systems. Bonde *et al.* (2004) found that hind feet lesions, which were caused most often by bursitis, increased the risk of lameness (OR = 2.5 for slightly lame sows and OR = 4.3 for markedly lame sows), a finding that is in keeping with the present study. It could be also argued that lame sows spend more time lying down, and that therefore they are more likely to develop bursitis and/or wounds – in other words, the causality might run in both directions here.

Conclusion

Herd prevalence of lameness in organic sows was lower in winter/spring, and leg problems increased the risk of lameness. Lameness was less prevalent in organic sow herds than it was in conventional herds, and sows with bursitis had an increased risk of being lame in both organic and conventional sow herds.

Acknowledgements

The study is part of the project 'Lameness and leg disorder in outdoor sows' and was supported by funds from Knowledge Centre for Animal welfare. The authors wish to thank the technicians and farmers who participated in the project.

References

Akos K and Bilkei G 2004. Comparison of the reproductive performance of sows kept outdoor in Croatia with that of sows kept indoors. Livestock Production Science 85, 293–298.

Bonde M and Sorensen JT 2003. Control of heath and welfare problems in organic sow herds. Newsletter from Danish Research centre for organic farming 3, 1–4.

Bonde M, Rousing T, Badsmand JH and Sørensen JT 2004. Associations between lying-down behaviour problems and body condition, limb disorders and skin lesions of lactating sows housed in farrowing crates in commercial sow herds. Livestock Production Science 87, 179–187.

Cox B and Bilkei G 2004. Lifetime reproduction performance of sows kept indoor and outdoor in Croatia. Veterinary Record 154, 569–570.

Dohoo I, Martin W and Stryhn H 2009. Veterinary epidemiology research, 2nd edition. p. 583. VER Inc., Charlattetown, Prince Edwards Island, Canada.

DMI 2013. Vejrarkiv. Danmarks Meteorologiske Institut. Retrieved July 27, 2013, from http://www.dmi.dk/vejr/arkiver/maanedsaesonaar/.

Dyrenes Beskyttelse 2010. Mærkekrav svin. Retrieved July 27, 2013, from http://www.dyrenes-beskyttelse.dk/hvad-g%C3%B8r-vi/landbrugsdyr/svin/m%C3%A6rkekrav-svin.

Engblom L, Lundeheim N, Strandberg E, Schneider Mdel P, Dalin AM and Anderson K 2008. Factors affecting length of production life in Swedish commercial sow. Journal of Animal Science 86, 432–441.

Heinonen M, Oravainen J, Orro T, Seppä-Lassila L, Ala-Kurikka E, Virolainen J, Tast A and Pletoniemi OAT 2006. Lameness and fertility of sows and gilts in randomly selected loose-housed herds in Finland. Veterinary Record 159, 383–387.

Jensen TB, Bonde MK, Kongsted AG, Toft N and Sørensen JT 2010. The interrelationships between clinical signs and their effect on involuntary culling among pregnant sows in group-housing systems. Animal 4, 1922–1928.

Pluym L, Van Nuffel A, Dewulf J, Cools A, Vangroenwegne F, Van Hoorebeke S and Maes D 2011. Prevalence and risk factors of hoof lesions and lameness in pregnant sows in two types of group housing. Veterinarni Medicina 56, 101–109.

Stalder KJ, Knauer M, Baas TJ, Rothschild MF and Mabry JW 2004. Sow longevity. Pig News and Information 25, 53N–74N.

USDA 2007. Swine 2006, part I: reference of swine health and management practices in the United States, 2006. USDA:APHIS:VS, CEAH, Fort Collins, Colorado.

Vestergaard K, Christensen G, Petersen LB and Wachmann H 2004. Afgangsårsager hos søer – samt obduktionsfund hos aflivede of selvdøde søer. Meddelelse nr 656, Landsudvalget for svin og Danskeslagterier, Denmark.

Welfare Quality® 2009. Welfare Quality® Assessment protocol for pigs. Welfare Quality® Consortium, Lelystad, Netherlands, ISBN/EAN 978-90-78240-05-1.